

Remarks

Applicant respectfully requests favorable reconsideration of this response and amendment, as well as consideration of the pending claims as amended herein. The Examiner is encouraged to contact the undersigned by telephone to facilitate any remaining questions or issues.

Status of Pending Claims:

Claims 216-220, 222-229, 231-232, 235, 237-253, 258-260, 342 and 350 are pending in this application.

There are no claims which are (Currently amended).

Claims 216, 218-219, 222-224, 227-229, 231-232, 235, 237-244, 247-250, 252-253, 258-260, 342 and 350 are (Previously presented).

Claims 217, 220, 225-226, 238, 245-246 and 251 are (Original).

There are no claims which are (New).

Claims 1-215, 221, 230, 233-234, 236, 254-257 are (Canceled).

Claims 261-341 and 343-349 are (Withdrawn).

Amendments to the Claims:

There are no claim amendments in this office action response.

Summary of Examiner's Claim Rejections:

Claims 216-220, 222, 223, 224, 328-240, 243, 248-253, 258, 342, are rejected under 35 U.S.C. 103(a) as being unpatentable over US 4841731 (Tindell) in view of U.S. 5388395 (Scharpf et al.). Claims 216-220, 222, 224, 228-229, 238-240, 243, 248-254, 256, 258, 342, are rejected under 35 U.S.C. 103(a) as being unpatentable over US 3459953 (Hughes et al) in view of Scharpf et al. Claims 225-227 are rejected under 35 U.S.C. § 103(a) as being unpatentable over U.S. 4841731 (Tindell) in view of Scharpf et al. and U.S. 5899072 (Gode). Claims 231, 235 are rejected under 35 U.S.C. § 103(a) as being unpatentable over U.S. 4841731 (Tindell) in view of Scharpf et al. and U.S. 5516359 (Kang et al). Claim 237 is rejected under 35 U.S.C. § 103(a) as being unpatentable over U.S. 4841731 (Tindell) in view of Scharpf et al. and U.S. 4440545 (Weidig). Claim 241 is rejected under 35 U.S.C. § 103(a) as being unpatentable over U.S. 4841731 (Tindell) in view of Scharpf et al. and U.S. 3975913 (Erickson). Claim 242 is rejected under 35 U.S.C. § 103(a) as being unpatentable over U.S. 4841731 (Tindell) in view of Scharpf et al. and US 2406605 (Hurd et al). Claims 244-247 are rejected under 35 U.S.C. §

103(a) as being unpatentable over U.S. 4841731 (Tindell) in view of Scharpf et al. and U.S. 6698183 (Thordarson). Claim 242 is rejected under 35 U.S.C. § 103(a) as being unpatentable over (Tindell) in view of U.S. 2406605 (Hurd et al.). Claims 259, 260 and 350 are rejected under 35 U.S.C. § 103(a) as being unpatentable over U.S. 4841731 (Tindell) in view of Scharpf et al. and U.S. 6212876 (Gregory et al.).

Marked-up Set of Claims (According to 37 CFR 1.121(c))

Claims 1 – 215 (Canceled)

216. (Previously presented) An engine comprising a combustion chamber, wherein a mixture of oxygen, as O₂, and hydrogen, as H₂, are combusted, wherein

at least a portion of said oxygen is obtained by the separation of air, wherein said separation of air is selected from the group consisting of: (a) cryogenic air separation, (b) membrane separation, and (c) pressure swing adsorption air separation and any combination thereof, wherein

at least a portion of the energy of combustion powers at least a portion of said air separation, and wherein

the temperature of combustion is at least partially controlled with the addition of water to said combustion chamber in a way that maintains combustion or combustion exhaust temperature.

217. (Original) The engine of claim 216, wherein mechanical rotating energy is created.

218. (Previously Presented) The engine of claim 217, wherein said rotating mechanical energy turns a generator to create electrical energy.

219. (Previously Presented) The engine of claim 216, wherein the steam produced by combustion turns a steam turbine, and wherein

said steam turbine turns a generator to create electrical energy.

220. (Original) The engine of claim 216, wherein heat is created.

221. (Canceled)

222. (Previously presented) The engine of claim 218 or 219, wherein at least a portion of said electrical energy is used in the electrolysis of water to hydrogen and oxygen, and wherein at least a portion of at least one of said hydrogen and oxygen is used in said mixture.

223. (Previously presented) The engine of claim 216, further comprising nitrogen or

argon in said mixture.

224. (Previously presented) The engine of claim 216, wherein said oxygen further comprises air.

225. (Original) The engine of claim 216, wherein at least a portion of the steam produced by combustion is converted to hydrogen by the corrosion of at least one metal.

226. (Original) The engine of claim 225, wherein the conversion of said steam into said hydrogen is increased by an electrical current in said metal(s).

227. (Previously presented) The engine of claim 225 or 226, wherein said hydrogen is at least partially used in said mixture.

228. (Previously presented) The engine of claim 216, wherein a generator turns due to the movement of air or water, and wherein
said generator creates electrical energy, and wherein
said electrical energy is at least partially utilized in the electrolysis of water to hydrogen and oxygen, and wherein
at least a portion of at least one of said hydrogen and oxygen is used in said mixture.

229. (Previously presented) The engine of claim 216, wherein a photovoltaic cell creates electrical energy, wherein
said electrical energy is at least partially used in the electrolysis of water to hydrogen and oxygen, and wherein
at least a portion of at least one of said hydrogen and oxygen is used in said mixture.

230. (Canceled)

231. (Previously presented) The engine of claim 216, wherein at least a portion of the nitrogen separated from air in said cryogenic air separation unit is used to cool any portion of at least one selected from a list consisting of: said cryogenic air separation unit, the storage of oxygen, the storage of hydrogen, electrolysis, coolant for said engine, said engine and any combination thereof.

232. (Previously presented) The engine of claim 231, wherein said nitrogen separated from air in said cryogenic air separation unit is at least partially used to cool air or water.

223 – 234. (Canceled)

235. (Previously presented) The engine of claim 216, wherein said oxygen separated from air is at least one of enriched oxygen, pure oxygen and very pure oxygen.

236. (Canceled)

237. (Previously Presented) The engine of claim 216, wherein at least one selected from a list consisting of a: corrosion inhibitor, chelant, dispersant and any combination therein is added to at least a portion of the water in said engine.

238. (Original) The engine of claim 216, wherein said engine performs at least one of: internal, turbine and heating combustion.

239. (Previously Presented) The engine of claim 216, wherein at least one of oxygen and hydrogen is stored in at least one of a cooled gas state and a liquid state by liquefaction.

240. (Previously Presented) The engine of claim 239, wherein compressor(s) for at least one of cooling and liquefaction is powered by at least one of said engine and a fuel cell.

241. (Previously Presented) The engine of claim 240, wherein said fuel cell is powered by hydrogen and at least one of oxygen and air.

242. (Previously Presented) The engine of claim 216, wherein at least one of said hydrogen and oxygen is stored in a mixture with frozen water crystals to form a gel.

243. (Previously presented) The engine of claim 216, wherein at least one selected from a list consisting of: hydrogen, oxygen and water is preheated prior to combustion with the energy from at least one selected from a list consisting of: ambient temperature, said engine, said engine exhaust, an electrical radiant heat source and any combination therein.

244. (Previously Presented) The engine of claim 217, wherein said mechanical rotating energy from said engine enters a transmission, wherein
said transmission engage in a manner that is inversely proportional to at least one of the torque and work output of said engine, and wherein
said transmission output mechanical rotating energy turn a generator to create electrical energy.

245. (Original) The engine of claim 244, wherein said transmission engage a flywheel capable of storing rotational kinetic energy, wherein
said flywheel turns said generator.

246. (Original) The engine of claim 244, wherein at least a portion of said electrical energy is used in the electrolysis of water to hydrogen and oxygen.

247. (Previously presented) The engine of claim 246, wherein at least a portion of at least one of said hydrogen and oxygen is used in said mixture.

248. (Previously Presented) The engine of claim 216 or 219, wherein a pressure control device is in said engine exhaust.

249. (Previously Presented) The engine of claim 216, wherein at least one of said engine combustion heat energy and said engine exhaust energy is used to heat at least one of a gas and a liquid.

250. (Previously Presented) The engine of claim 249, wherein at least one of the gas is air and the liquid is water.

251. (Original) The engine of claim 250, wherein said exhaust discharge directly into said air or water.

252. (Previously presented) The engine of claim 216, wherein at least a portion of said engine is insulated.

253. (Previously presented) The engine of claim 216, wherein hydrogen is separated

from at least one selected from a list consisting of: water, air, nitrogen, oxygen and any combination thereof within said air separation unit.

254 – 257. (Canceled)

258. (Previously presented) The engine of claim 216, wherein the temperature of said engine exhaust is at least partially cooled with the addition of water to said engine exhaust.

259. (Previously presented) The engine of claim 258, comprising jet propulsion.

260. (Previously presented) The engine of claim 216 or 258, comprising rocket propulsion.

Claims 261 - 341 (Withdrawn)

342. (Previously presented) The engine of claim 216, wherein said engine comprises a turbine.

Claims 343 - 349 (Withdrawn)

350. (Previously presented) The engine of claim 256, comprising jet propulsion wherein said air is stoichiometrically increased in the jet intake for hydrogen thermodynamics and/or to operate with excess air for cooling.

Examiner Statements

Examiner Statement

Applicant asked the Examiner to contact him to expedite the progress of this application. The Examiner already presented his proposed allowable claims in the previous Office Action and would like to repeat herein. "First of all, for the purpose of expediting the examining process, the Examiner would like to suggest the only independent claim 216 be amended to further include a combination of 1) the electrolysis chamber in claim 228, and 2) the hydrogen gel with frozen water crystals in claim 242 to put this application in condition for allowance. Right now, this application is still rejected because of the following reasons."

Applicant's Response

Applicant appreciates the Examiner's position regarding claim allowance with the aforementioned limitation(s). However, Applicant believes that such added limitations are not warranted given the non-obviousness of the instant invention. Applicant would like to respectfully present to the Examiner knowledge and appreciation of the work load at the USPTO; however, Applicant does not wish to make claim amendments which can affect the property and rights of Applicant "for the purpose of expediting the examining process".

Examiner Statement

Applicant argued "to power" is different from "to regenerate", and Scharpf et al only teaches "to generate". The Examiner strongly disagrees. Please note the combusted products is inside the coal gasifier 70, that drives the steam generator 50, then the steam regenerate the air separation unit 80. Because the input energy all come from the coal gasifier 70, the combusted products from said gasifier is clearly used to drive or power both the steam generator and the air separation unit. Also,

please note "to regenerate" is broader than "to power". As evidenced by Applicant's submitted dictionary pages, "to power" is simply a source or means of supplying energy. The steam in Scharpf et al is clearly a supply energy source for the air separation unit.

Applicant's Response

The Examiner states that Applicant argues "[a]nd Scharpf et al only teaches to generate". As Applicant reviews his argument and dictionary references from the Office Action Response dated 10/01/07, there is no argument or dictionary definition relating to "generate". Applicant herein repeats the submitted dictionary definitions for the Examiner.

¹**regenerate 1** : formed or created again;...**3** : restored to a better, or more worthy state.

And, "power" is defined as:

¹**power 1** : ...**6 a** : a source or means of supplying energy : esp. ELECTRICITY; **b** : MOTIVE POWER; **c** : the time rate at which work is done or energy emitted or transferred; ...

syn POWER, FORCE, ENRGY, STRENGHT, MIGHT means the ability to exert effort, power may imply latent, external physical, mental or spiritual ability to act or be acted upon, FORCE implies the actual effective exercise of power, ENERGY applies to power expended or capable of being transformed into work, STRENGTH applies to the property of a person or thing that makes possible the extension of force or the withstanding of strain, pressure or attack; MIGHT implies great or overwhelming power or strength.

Therefore, "regenerate" is not a genus to the species "power"; and, "regenerate" cannot encompass "power". Such is impossible. This is while Scharpf et al do not use steam as a power source for the separation of air. In contrast, Scharpf et al teach the use of steam to the air separation unit to regenerate the unit; this is while regenerate is not to power. And, the instant claim reads "**at least a portion of the energy of combustion powers at least a portion of said air separation**"; there is no way that any air separation is performed during media regeneration. This is all while, it is found that Scharpf et al add nitrogen to the combustion of hydrogen in air while said combustion powers said air separation to further produce nitrogen for said combustion.

Applicant respectfully presents to the Examiner a description of coal gasification from Wikipedia. Wikipedia states:

Gasification is a process that converts carbonaceous materials, such as **coal**, **petroleum**, or **biomass**, into **carbon monoxide** and **hydrogen** by reacting the raw material at high temperatures with a controlled amount of **oxygen**. The resulting gas mixture is called **synthesis gas** or **syngas** and is itself a fuel. Gasification is a very efficient method for extracting **energy** from many different types of organic materials, and also has applications as a clean **waste disposal** technique.

The advantage of gasification is that using the **syngas** is more efficient than direct combustion of the original fuel; more of the energy contained in the fuel is extracted. **Syngas** may be burned directly in internal combustion engines, used to produce **methanol** and **hydrogen**, or converted via the **Fischer-Tropsch process** into **synthetic fuel**. Gasification can also begin with materials that are not otherwise useful fuels, such as **biomass** or **organic waste**. In addition, the high-temperature combustion refines out corrosive ash elements such as chloride and potassium, allowing clean gas production from otherwise problematic fuels.

Gasification of **fossil fuels** is currently widely used on industrial scales to generate **electricity**. However, almost any type of **organic** material can be used as the raw material for gasification, such as **wood**, **biomass**, or even **plastic waste**. Thus, gasification may be an important technology for **renewable energy**. In particular **biomass** gasification is **carbon neutral**.

Gasification relies on chemical processes at elevated temperatures $>700^{\circ}\text{C}$, which distinguishes it from biological processes such as **anaerobic digestion** that produce **biogas**.

In a gasifier, the carbonaceous material undergoes several different processes:

1. The **pyrolysis** (or devolatilization) process occurs as the carbonaceous particle heats up. Volatiles are released and **char** is produced, resulting in up to 70% weight loss for coal. The process is dependent on the properties of the carbonaceous material and determines the structure and composition of the char, which will then undergo gasification reactions.
2. The **combustion** process occurs as the volatile products and some of the char reacts with oxygen to form **carbon dioxide** and **carbon monoxide**, which provides heat for the subsequent gasification reactions. Letting C represent a carbon-containing **organic compound**, the basic reaction here is
$$\text{C} + \frac{1}{2}\text{O}_2 \rightarrow \text{CO}$$
3. The **gasification** process occurs as the char reacts with carbon dioxide and steam to produce carbon monoxide and hydrogen, via the reaction
$$\text{C} + \text{H}_2\text{O} \rightarrow \text{H}_2 + \text{CO}$$
4. In addition, the **reversible** gas phase **water gas shift reaction** reaches **equilibrium** very fast at the temperatures in a gasifier. This balances the concentrations of carbon monoxide, steam, carbon dioxide and hydrogen.
$$\text{CO} + \text{H}_2\text{O} \leftrightarrow \text{CO}_2 + \text{H}_2$$

In essence, a limited amount of oxygen or air is introduced into the reactor to allow some

of the organic material to be "burned" to produce **carbon monoxide** and **energy**, which drives a second reaction that converts further organic material to **hydrogen** and additional **carbon dioxide**.

Applicant has no teaching as to coal gasification or the gasification of any hydrocarbon. Applicant respectfully presents to the Examiner that Scharpf et al teach within figures 1 and 2 the recovery of heat from coal gasification 70 performed within heat recovery steam generator 50 and the use of steam generated within heat recovery steam generator 50 to drive a steam turbine 60 to generate power. This teaching in Scharpf et al is in strong contrast to instant independent claim 216, which states:

216. An engine comprising a combustion chamber, **wherein a mixture of oxygen, as O₂, and hydrogen, as H₂, are combusted, wherein**
at least a portion of said oxygen is obtained by the separation of air, wherein
said separation of air is selected from the group consisting of: (a) cryogenic air separation, (b) membrane separation, and (c) pressure swing adsorption air separation and any combination thereof, wherein
at least a portion of the energy of combustion powers at least a portion of said air separation, and wherein
the temperature of combustion is at least partially controlled with the addition of water to said combustion chamber in a way that maintains combustion or combustion exhaust temperature. **(emphasis added)**

There is no linkage in figure 1, figure 2 or teaching within the specification of Scharpf et al between either: coal gasification unit 70, heat recovery steam generator 50 or steam turbine 60 to power air separation unit 80. Therefore, there is no teaching or suggestion in Scharpf et al to drive or power air separation from a coal gasification unit, steam generator or steam turbine. This is while Scharpf et al teaches within figures 1 and 2, as well as within the specification, to power air separation unit 80 with the combustion of fuel gas in combustor 30, wherein nitrogen from said air separation 80 is sent to said fuel gas combustor 30. This is while both the before mentioned Wikipedia reference and Scharpf et al teach that fuel gas comprises hydrogen. Specifically, Scharpf et al states in column 3 lines 23 to 25:

BRIEF DESCRIPTION OF THE DRAWING

FIGS. 1 and 2 are schematic diagrams of two embodiments of the process of the present invention.

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Therefore, there are two embodiments in Scharpf et al. This is while column 3 line 27 to 65 states:

DETAILED DESCRIPTION OF THE INVENTION

The present invention is an improvement to a process for the production of work using a gas turbine either in a simple or a combined cycle configuration. The improvement is particularly suited to the process, wherein at least a portion of the oxygen product produced by the cryogenic air separation unit is reacted with a carbonaceous feedstock in a gasification unit to produce the fuel gas, which is rich in carbon monoxide and hydrogen. The carbonaceous feedstock reacted in the gasifier unit can be coal, petroleum coke, tar sands bitumen, tar sand emulsion, municipal wastes, petroleum residua, waste oil or mixtures thereof.

The improvement efficiently uses the excess nitrogen from an air separation unit. As stated above, the improvement to the process in its broadest sense comprises cooling at least a portion of the nitrogen product from the air separation unit and combining such cooled, nitrogen product with the feed air being fed to the gas turbine air compressor. In order to fully understand the improvement of the present invention, it will be discussed in detail with reference to two embodiments.

The improvement to the process, in its primary embodiment, takes the waste nitrogen stream produced by an elevated pressure air separation unit and passes it through an expander to generate power and to chill the nitrogen stream to subambient temperatures. The chilled stream is then fed to the inlet of the air compressor for the gas turbine, displacing some of the ambient temperature air feed. This modification cools and densifies the gas turbine compressor feed, increasing the total gas throughput of the gas turbine compressor. As a side effect, since the nitrogen stream is depleted in oxygen relative to the normal feed air to the gas turbine compressor, the oxygen content of the oxidant will be reduced, resulting in lower peak flame temperatures that will in turn result in lower NO_x generation. A flow diagram of this process is shown in FIG. 1.

And, column 4 line 56 to column 5 line 22 state:

The improvement to the process, in the alternate embodiment, is particularly suited to the process when it utilizes an air separation unit operating at conventional low pressures and where the available nitrogen is not saturated with water. The alternative embodiment

uses a saturation cooler to cool the nitrogen stream before it enters the gas turbine compressor inlet. This cooling and saturating has similar effects to those in the primary application described above. In addition, this
65 saturator/cooler will increase the mass flow of the nitrogen stream and increase its heat capacity, further improving the process. This optional modification may be employed with low or elevated pressure nitrogen

streams and, also, in conjunction with the primary expander configuration described above. Depending on the relative humidity of the main air feed, the saturator can be run to varying levels of saturation to prevent condensation problems in the gas turbine compressor. 5
The flow diagram for this option (for a case without the primary expander) is shown in FIG. 2 with the key aspects of the modification highlighted by the shaded box. Similar process streams and equipment in FIGS. 1 and 2 share the same identification number. 10

With reference to FIG. 2, feed air, in line 10, and chilled, saturated nitrogen, in line 192, is compressed in gas turbine air compressor 20 to produce a compressed, combustion air stream. This compressed, combustion air stream, in line 22, is then fed to and combusted with 15
fuel gas, in line 62, and, optionally, steam, in line 52, in combustor 30 producing a combustion product stream. This combustion product stream, in line 32, is fed to and expanded in gas turbine expander 40 thereby producing a hot exhaust gas stream and electricity. Typically, gas 20
turbine expander 40 and gas turbine air compressor 20 are mechanically linked.

Therefore, Scharpf et al teach the combustion of hydrogen with a feed of nitrogen to combustion from a cryogenic air separation unit, wherein the cryogenic air separation unit is powered by said hydrogen combustion. This is in strong contrast to Applicant's teachings for the use of oxygen in the combustion of hydrogen, wherein the oxygen is from an air separation unit powered by said combustion of hydrogen.

This striking difference between the teaching of Scharpf et al and that of Applicant is furthered by the teaching of Applicant in the instant specification for the removal of nitrogen from the combustion chamber. Specifically, Applicant states in paragraph 61:

[0061] Air has traditionally been used as the combustion oxidant (O_2 in air). The combustion of O_2 with H_2 , without the inclusion of N_2 and/or Ar or with a minimal inclusion of N_2 and/or Ar from air, improves internal combustion energy output by over 300 percent. This aspect of the instant invention can be readily seen by comparing a

combustion system which utilizes air for the oxidant, wherein air is approximately only 20 percent O₂ and 78 percent N₂, and a combustion system which utilizes very pure O₂ as the oxidant. Nitrogen reduces the combustion temperature while endothermically producing NO_x, thereby creating pollution while reducing engine efficiency. Since air is approximately 78 percent N₂, nearly 78 percent of the combustion mixture in a traditional combustion engine provides no energy during combustion, and in actuality, reduces the energy output of combustion. While the N₂ in air can keep the combustion temperature down, thereby producing exhaust gas temperatures approximately near or below 1000 °F, so that the combustion temperature is not harmful to traditional materials of engine construction, the addition of H₂O to an O₂/H₂ fuel mixture approaches isothermal combustion producing steam while cooling the temperature of combustion, thereby converting combustion heat energy into an energy form that is easily utilized and/or recycled. The inclusion of N₂ does not provide the ability of energy recycle. The same discussion applies to Ar.

In light of the above facts, Applicant further wishes to respectfully present to the Examiner that Applicant has identified "the source of the problem" not identified by Scharpf et al, e.g. the removal of nitrogen from rather than the addition of nitrogen to the combustion of hydrogen. Applicant would like to respectfully refer the Examiner to MPEP 2141.02, which states:

[A] patentable invention may lie in the discovery of the source of a problem even though the remedy may be obvious once the source of the problem is identified. This is part of the 'subject matter as a whole' which should always be considered in determining the obviousness of an invention under 35 U.S.C. § 103." *In re Sponnoble*, 405 F.2d 578, 585, 160 USPQ 237, 243 (CCPA 1969). **(Emphasis added)**

Examiner Statement

Applicant argued Hurd does not disclose water in the "dry-ice" condenser and further argued dry-ice is carbon dioxide. The Examiner again strongly disagrees. Please note column 2, lines 46-49 of Hurd, "A portion of the condensate was hydrolyzed in water to give a gel". That clearly explains there is water and hydrogen in said frozen condenser; and of course, water is also frozen due to that frozen temperature.

Applicant's Response

Applicant would respectfully wish to point out to the Examiner that the Examiner did not properly cite the entire paragraph within Hurd. The entire paragraph states:

40 *Example 3*
A mixture of silicon tetrachloride vapor and hydrogen gas in 1:2 mol ratio was passed over granular zinc at 350–400°. A liquid product was
45 condensed from the effluent gas mixture by means of a Dry-Ice condenser. A portion of the condensate was hydrolyzed in water to give a gel which upon treatment with alkali solution produced a vigorous evolution of gas. A distil-
50 lation of the product revealed the presence of volatile compounds boiling below the boiling point of silicon tetrachloride. When these low boiling compounds were treated with dilute alkali the gas evolution was much more vigorous than
55 in the case of the gel.

Therefore, Hurd presents a mixture of silicon tetrachloride vapor and hydrogen gas in a 1:2 ratio. Then a liquid product from the mixture is condensed by means of a dry ice condenser (dry ice is frozen at -79°C ; therefore, it only stands to reason that the condensed liquid contains the silicon tetrachloride, which has a freezing point of -70°C , and not the hydrogen as hydrogen is not a liquid until near -259°C . Also, there could not have been any water in the condensed liquid at that temperature as water freezes at 0°C). Then, the condensate from the condenser was hydrolyzed in water to give a gel. Therefore, the gel was formed in water and with water by hydrolyzation of the condensate, e.g. silicon tetrachloride. There is no mention in Hurd of a gel formed from hydrogen with frozen water crystals, as is taught in the instant invention. Applicant respectfully presents to the Examiner that the Examiner is reading materials and chemistry into Hurd which does not exist within Hurd.

Examiner Statement

Applicant argued Scharpf uses oxygen inside a coal gasifier which is different from this instant invention which only teaches the combustion of oxygen with hydrogen. The Examiner has noted Applicant many times before that Applicant should not attack the references separately in a 103 rejection. The primary reference Tindell already

teaches the concept of using oxygen, hydrogen in a combustion chamber 31. Scharpf is used only to show the air separation unit. Also, it does not seem Applicant fully understand the Scharpf reference. Please note the oxygen from the air separation unit in Scharpf going to a coal gasifier 70 which is a type of combustion chamber.

Furthermore, the outlet of said coal gasifier goes to a combustor 30 which is another combustion chamber. The nitrogen goes to an expander 90 through line 86, but also goes to said combustor 30 through compressor 20 and exhaust line 22. The combustor 30 should have all nitrogen, hydrogen and oxygen in there.

Applicant's Response

Applicant appreciates the Examiner's discussion and argument. Applicant respectfully presents to the Examiner, as done so above, that Scharpf et al does NOT teach the air separation unit portion of the instant independent claim. Scharpf et al does NOT teach:

216. An engine comprising a combustion chamber, wherein a mixture of oxygen, as O_2 , and hydrogen, as H_2 , are combusted, wherein

at least a portion of said oxygen is obtained by the separation of air, wherein said separation of air is selected from the group consisting of: (a) cryogenic air separation, (b) membrane separation, and (c) pressure swing adsorption air separation and any combination thereof, wherein

at least a portion of the energy of combustion powers at least a portion of said air separation, and wherein

the temperature of combustion is at least partially controlled with the addition of water to said combustion chamber in a way that maintains combustion or combustion exhaust temperature. **(emphasis added)**

In contrast to Applicant, Scharpf et al teach the use of **nitrogen from a cryogenic air separation unit** in combustion with hydrogen, **therein diluting available oxygen**. This is while Applicant teaches a different problem and solution than that of Scharpf et al., wherein **Applicant teaches concentrating the oxygen** while removing nitrogen from combustion by the use of said **oxygen from a cryogenic air separation unit**; therefore, Scharpf et al teach away from the instant invention. **Scharpf et al, as a teaching, renders the instant invention and claims irrational to one of ordinary skill in the art.**

Examiner Statement

Regarding other 103 rejections including Gode, Kang et al, Weidig, Erickson, Thodarson, the Examiner has carefully reviewed all arguments including those in the declaration, but the arguments are not found persuasive. Even though the Examiner agrees with Applicant that "a dependent claim needs to include all of claims restrictions (or limitations) of the independent claim, as well as the restrictions of the dependent claims, the Examiner fails to find any patentably distinct subject matter in the dependent claims. Therefore, it's concluded that these dependent claims should stand and fall with the independent claims.

Applicant's Response

Applicant respectfully presents to the Examiner that Applicant traverses the Examiner's rejections of independent claim 216 in this Office Action Response. Due to said traversal, Applicant respectfully requests an allowance of all dependent claims presented herein along with independent claim 216.

Examiner Statement

The Examiner strongly recommends Applicant to accept his proposed allowed claims as noted above to expedite the progress of this application.

Applicant's Response

As previously presented above by Applicant, Applicant would like to respectfully present to the Examiner knowledge and appreciation of the work load at the USPTO; however, Applicant does not wish to make claim amendments, which can affect the property and rights of Applicant "to expedite the progress of this application".

Examiner's 35 USC 103(a) Rejections**Examiner's Rejection**

Claims 216-220, 222, 223, 224, 238-240, 243, 248-253, 258 and 342 over Tindel in view of Scharpf et al. As Applicant wishes not to repeat the Examiner's rejection again in its entirety, Applicant notes the Examiner's argument at the end of his rejection to state:

~~separation unit being powered partly by the combustion energy.~~ Scharpf et al discloses an air separation unit 80 being powered partly by the steam (column 4, lines 20-22), which is a part of the combustion power. It would have been obvious to provide an air separation unit in Tindell as taught by Scharpf et al for the purpose of more effectively forming oxygen for the combustion process. Regarding claim 223, Tindell does not disclose the use of nitrogen. Scharpf et al is relied upon to disclose it's well known to use nitrogen in the inlet of the combustion chamber for the purpose of improving the cooling function of the input fluid. It would have been obvious at the time the invention was made to a person having ordinary skill in the art to inject nitrogen in Tindell as taught by Scharpf et al for the purpose of improving the cooling function of the input fluid.

Applicant's Response

As presented previous to the Examiner, to regenerate and to power are not the same while regeneration cannot separate air, as is claimed in the instant claims. Scharpf et al does not teach the powering air separation from a combustion source, wherein oxygen from the combustion source is used in said combustion.

Applicant respectfully presents again to the Examiner that Scharpf et al does not teach to power air separation, wherein the oxygen from the air separation is used in the combustion of hydrogen with oxygen. In the alternative, Scharpf et al does not teach to combust oxygen from air separation, wherein said combustion powers said air separation. Therefore, the Examiner's cited rejection does not comprise all of the claim elements within independent claim 216. (Ref.

MPEP 2143.03)

Regarding claim 223, Applicant does not use nitrogen to "improve the cooling function of the input fluid". In strong contrast, Applicant uses water for the cooling of the combustion of hydrogen with oxygen. Further, the Scharpf et al nitrogen cooling teaching teaches away from instant claim 216.

In light of the many above arguments by Applicant, the Examiner's cited combination of Tindel in view of Scharpf is traversed. Applicant herein respectfully requests an allowance of independent claim 216, along with all of the dependant claims presented herein which depend upon independent claim 216.

Examiner's Rejection

Claims 216-220, 222, 223, 224, 228-229, 238-240, 243, 248-253, 258 and 342 over Hughes et al in view of Scharpf et al. As Applicant wishes not to repeat the Examiner's rejection again in its entirety, Applicant notes the Examiner's argument at the end of his rejection to state:

~~powered partly by the combustion energy.~~ Scharpf et al discloses an air separation unit 80 being powered partly by the steam (column 4, lines 20-22), which is a part of the combustion power. It would have been obvious to provide an air separation unit in Hughes et al as taught by Scharpf et al for the purpose of more effectively forming oxygen for the combustion process. Regarding claim 223, Hughes et al does not disclose the use of nitrogen. Scharpf et al is relied upon to disclose it's well known to use nitrogen in the inlet of the combustion chamber for the purpose of improving the cooling function of the input fluid. It would have been obvious at the time the invention was made to a person having ordinary skill in the art to inject nitrogen in Hughes et al as taught by Scharpf et al for the purpose of improving the cooling function of the input fluid.

Applicant's Response

As presented previous to the Examiner, to regenerate and to power are not the same while regeneration cannot separate air, as is claimed in the instant claims. Therefore, Scharpf et al does not in any way teach the powering of air separation from a combustion source.

Applicant respectfully presents again to the Examiner that Scharpf et al does not teach to power air separation, wherein the oxygen from the air separation is used in the combustion of hydrogen with oxygen. In the alternative, Scharpf et al does not teach to combust oxygen from air separation, wherein said combustion powers said air separation. Therefore, the Examiner's cited rejection does not comprise all of the claim elements within independent claim 216. (Ref. MPEP 2143.03)

Regarding claim 223, Applicant does not use nitrogen to "improve the cooling function of the input fluid". In strong contrast, Applicant uses water for the cooling of the combustion of hydrogen with oxygen. Further, the Scharpf et al nitrogen cooling teaching teaches away from instant claim 216.

In light of the many above arguments by Applicant, the Examiner's cited combination of Tindel in view of Scharpf is traversed. Applicant herein respectfully requests an allowance of independent claim 216, along with all of the dependant claims presented herein which depend upon independent claim 216.

Examiner's Rejection

Claims 225-227 over Tindel in view of Scharpf and Gode

Applicant's Response

Applicant would like to respectfully present to the Examiner that once Applicant has traversed a prime facie case of obviousness relating to an independent claim, in this case claim 216, Applicant has also traversed the rejection of any claim which depends upon the independent claim, reference MPEP 2143.03. Therefore, as Applicant has respectfully traversed the Examiner's 35 U.S.C. 103(a) rejection of independent claim 216, Applicant respectfully requests an allowance of claims 225-277.

Examiner's Rejection

Claims 231, 235 over Tindel in view of Scharpf and Kang

Applicant's Response

Applicant respectfully presents to the Examiner that once Applicant has traversed a prime facie case of obviousness relating to an independent claim, in this case claim 216, Applicant has also traversed the rejection of any claim which depends upon the independent claim, reference MPEP 2143.03. Therefore, as Applicant has respectfully traversed the Examiner's 35 U.S.C. 103(a) rejection of independent claim 216, Applicant respectfully requests an allowance of claims 231 and 235.

Examiner's Rejection**Claim 237 over Tindel in view of Scharpf and Weidig****Applicant's Response**

Applicant would like to respectfully present to the Examiner that once Applicant has traversed a prime facie case of obviousness relating to an independent claim, in this case claim 216, Applicant has also traversed the rejection of any claim which depends upon the independent claim, reference MPEP 2143.03. Therefore, as Applicant has respectfully traversed the Examiner's 35 U.S.C. 103(a) rejection of independent claim 216, Applicant respectfully requests an allowance of claim 237.

Examiner's Rejection**Claim 241 over Tindel in view of Scharpf and Erickson****Applicant's Response**

Applicant would like to respectfully present to the Examiner that once Applicant has traversed a prime facie case of obviousness relating to an independent claim, in this case claim 216, Applicant has also traversed the rejection of any claim which depends upon the independent claim, reference MPEP 2143.03. Therefore, as Applicant has respectfully traversed the Examiner's 35 U.S.C. 103(a) rejection of independent claim 216, Applicant respectfully requests an allowance of claim 241.

Examiner's Rejection**Claim 242 over Tindel in view of Scharpf and Hurd****Applicant's Response**

Applicant would like to respectfully refer the Examiner to Applicant's previous argument herein. Applicant respectfully requests an allowance of claim 242.

Examiner's Rejection**Claims 259-260 and 350 over Tindel in view of Scharpf and Gregory**

Applicant's Response

Applicant would like to respectfully present to the Examiner that once Applicant has traversed a prime facie case of obviousness relating to an independent claim, in this case claim 216, Applicant has also traversed the rejection of any claim which depends upon the independent claim, reference MPEP 2143.03. Therefore, as Applicant has respectfully traversed the Examiner's 35 U.S.C. 103(a) rejection of independent claim 216, Applicant respectfully requests an allowance of claims 259-260 and 350.

Examiner's Rejection

Claims 244-247 over Tindel in view of Scharpf and Thordarson

Applicant's Response

Applicant would like to respectfully present to the Examiner that once Applicant has traversed a prime facie case of obviousness relating to an independent claim, in this case claim 216, Applicant has also traversed the rejection of any claim which depends upon the independent claim, reference MPEP 2143.03. Therefore, as Applicant has respectfully traversed the Examiner's 35 U.S.C. 103(a) rejection of independent claim 216, Applicant respectfully requests an allowance of claims 244-247.

Further Examiner Argument

Applicant's request for reconsideration has been acknowledged and entered.

The Examiner would like to comment on the two declarations dated October 1st, 2007.

First, the Examiner has considered those declarations carefully, he did not dismiss the secondary considerations out of hand at presented by Applicant in his request for reconsideration.

Second, the Examiner would like to point out why the declarations are not found persuasive with the following remarks.

1) The declarations present the long-felt need of the water combustion technology in this application. Both declarations are directed to the invention as a whole, not the claimed invention. As noted in the Examiner's Office Action, it's recognized that Applicant's invention has some allowable subject matter, and the Examiner did propose an allowable claim, and Applicant refused to accept the Examiner's proposal. Because the declarations fail to present any facts/opinions regarding the claimed invention, and why the claims are allowable over the applied references, the declarations are not found persuasive. Please note just because the application has some allowable subject matter does not mean the claims of this application are allowable at this moment.

2) Please also note the MPEP 716,04, "Second, the long-felt need must not have been satisfied by another before the invention by applicant". As evidenced by the Examiner's Office Actions, the claimed inventions of Applicant are not allowable over the pending rejections.

3) Even if the declarations provide opinions about the claimed invention and the pending rejections, it's within the Examiner's authority to make his decision based on the experience of a person having ordinary skill in the art.

Applicant's Response

In reference to item 1, Applicant respectfully wishes to refer the Examiner to the Declaration of Mr. Vaughan, who describes himself as one of expert skill in the art, wherein Mr. Vaughan states:

- In paragraph 3e "As I have read and understand, the invention of Mr. Haase, U.S. Patent Application 10/790,316, proposes a method and an apparatus to combust a pure form of hydrogen with a pure form of oxygen, wherein a portion of the combustion energy is used to cryogenically distill air as a means to provide a pure form of oxygen

to combustion. It is my opinion that this technique and the claims therein answer a long felt industry need known by those of ordinary and of expert skill in the art, as well as a long felt need of humanity."

- In paragraph 3f "As I have read and understand the invention of Mr. Haase, U.S. Patent Application 10/790,316, proposes a method and an apparatus to combust a pure form of hydrogen with a pure form of oxygen, wherein a portion of the combustion energy is used to cryogenically distill air to provide a pure form of oxygen to combustion. It is my understanding that this approach will increase the amount of hydrogen and of oxygen in the combustion chamber, thereby improving available torque per cubic inch of combustion chamber. It is my opinion that this teaching and the claims therein answer a long felt industry need known by those of ordinary and of expert skill in the art, as well as a long felt need of humanity."

In reference to item 1, Mr. Walker, who describes himself as one of ordinary skill in the art states:

- In paragraph 7, "I would state that a method or apparatus to combust hydrogen with a pure form of oxygen, as taught in U.S. Patent Application 10/790,316 and claimed therein, answers said long felt need."
- In paragraph 8, "As I have read and understand the invention of Mr. Haase, U.S. Patent Application 10/790,316 proposes a method and an apparatus to combust a pure form of hydrogen with a pure form of oxygen, wherein a portion of the combustion energy is used to cryogenically distill air as a means to provide a pure form of oxygen to combustion. It is my opinion that this teaching and the claims therein answer a long felt industry need known by those of ordinary and of expert skill in the art, as well as a long felt need of humanity."

Further, Applicant would like to respectfully present to the Examiner that Mr. Walker specifically states that the **claimed invention** answers a long felt need. This is while both declarations, that of Mr. Vaughan and of Mr. Walker, make statements which read directly on independent claim 216.

In relation to item 2, there is no other known or presented solution to the long felt need of a combustion system presented and claimed in the instant application. This is obvious as the Examiner did not present an alternate solution within his argument. This is also evidenced

within the declarations of Mr. Vaughan and Mr. Walker.

In relation to item 3, Applicant would like to respectfully present to the Examiner that Mr. Walker is one of ordinary skill in the art. Further, Applicant presents to the Examiner disbelief from one of at least ordinary skill in the art, Mr. James Kessling of the US Department of Defense. Applicant presents herein argument between Applicant and the US DOD, specifically, Mr. Kessling, relating to the claimed invention, wherein Mr. Kessling expressed paragraph upon paragraph of disbelief. Said argument is in the form of e-mail communication between Applicant and Mr. Kessling. Mr. Kessling did have benefit of the instant application and other material from applicant. Said e-mail communication is presented to the Examiner by Applicant in the form of a declaration so as to properly present to the Examiner Applicant's business records. Further still, Applicant presented said e-mail communication to Mr. Walker, who upon review of said e-mail communication, has prepared the attached declaration. Within his declaration, Mr. Walker states:

- In paragraph 4, "A method of hydrogen combustion as claimed and taught in the styled patent application was not obvious to me prior to the teachings of the inventor. Further, I cannot envision the claims and teachings within the styled patent application to be obvious to those of ordinary skill in the art of combustion science without the teachings of the inventor, as provided in the styled patent application."
- In paragraphs 5 and 6, "My belief in the non-obviousness of the claims and teachings within the styled patent application are exemplified in the interchange between the inventor and the U.S. Department of Defense, as evidenced herein in Exhibit A. I have reviewed the interchange, finding the skeptical and rather aggressive argument provided by Mr. Kessling and the U.S. DOD to leave the styled invention as non obvious to the U.S. DOD; this is while a combustion system as taught in the styled patent application should be of interest to an organization such as the U.S. DOD. It is only reasonable that Mr. Kessling, the U.S. DOD and Mr. Kessling's colleagues are of at least ordinary skill in the art of combustion science."
- In paragraphs 7 and 8, "Other than the teachings within the styled patent application, at this time there is no known method or apparatus to combust hydrogen with a pure form of oxygen without storage of oxygen. This is while oxygen is a rather combustible and dangerous material to store. I would state that a method or apparatus to combust hydrogen with a pure form of oxygen, as taught

in U.S. Patent Application 10/790,316 and claimed therein, is non-obvious to those of ordinary skill in the art of combustion science without the teachings of the styled patent application and answers said long felt need.

- In paragraph 9, "As I have read and understand, the invention of Mr. Haase, U.S. Patent Application 10/790,316 and his claims, propose a method and an apparatus to combust a pure form of hydrogen with a pure form of oxygen, wherein a portion of the combustion energy is used to cryogenically distill air as a means to provide a pure form of oxygen to combustion. It is my opinion that this teaching and the claims therein are non-obvious without the teachings of the styled patent application while answering a long felt industry need known by those of ordinary and of expert skill in the art, as well as a long felt need of humanity."

Applicant has respectfully responded to and adequately presented evidence to traverse the Examiner's rejection of the presented declarations.

Applicable Case Law

MPEP 2143.03

To establish *prima facie* obviousness of a claimed invention, all the claim limitations must be taught or suggested by the prior art. *In re Royka*, 490 F.2d 981, 180 USPQ 580 (CCPA 1974). "All words in a claim must be considered in judging the patentability of that claim against the prior art." *In re Wilson*, 424 F.2d 1382, 1385, 165 USPQ 494, 496 (CCPA 1970). If an independent claim is nonobvious under **35 U.S.C. 103**, then any claim depending therefrom is nonobvious. *In re Fine*, 837 F.2d 1071, 5 USPQ2d 1596 (Fed. Cir. 1988).

MPEP 716.04

Establishing long-felt need requires objective evidence that an art recognized problem existed in the art for a long period of time without solution. The relevance of long-felt need and the failure of others to the issue of obviousness depends on several factors. First, the need must have been a persistent one that was recognized by those of ordinary skill in the art. *In re Gershon*, 372 F.2d 535, 539, 152 USPQ 602, 605 (CCPA 1967) ("Since the alleged problem in this case was first recognized by appellants, and others apparently have not yet become aware of its existence, it goes without saying that there could not possibly be any evidence of either a long felt need in the . . . art for a solution to a problem of dubious existence or failure of others skilled in the art who unsuccessfully attempted to solve a problem of which they were not aware."); *Orthopedic Equipment Co., Inc. v. All Orthopedic Appliances, Inc.*, 707 F.2d 1376, 217 USPQ 1281 (Fed.

Cir. 1983) (Although the claimed invention achieved the desirable result of reducing inventories, there was no evidence of any prior unsuccessful attempts to do so.).

Second, the long-felt need must not have been satisfied by another before the invention by applicant. *Newell Companies v. Kenney Mfg. Co.*, 864 F.2d 757, 768, 9 USPQ2d 1417, 1426 (Fed. Cir. 1988) (Although at one time there was a long-felt need for a "do-it-yourself" window shade material which was adjustable without the use of tools, a prior art product fulfilled the need by using a scored plastic material which could be torn. "[O]nce another supplied the key element, there was no long-felt need or, indeed, a problem to be solved".)

Third, the invention must in fact satisfy the long-felt need. *In re Cavanagh*, 436 F.2d 491, 168 USPQ 466 (CCPA 1971).

Long-felt need is analyzed as of the date the problem is identified and articulated, and there is evidence of efforts to solve that problem, not as of the date of the most pertinent prior art references. *Texas Instruments Inc. v. Int'l Trade Comm'n*, 988 F.2d 1165, 1179, 26 USPQ2d 1018, 1029 (Fed. Cir. 1993).

MPEP 2141.02

[A] patentable invention may lie in the discovery of the source of a problem even though the remedy may be obvious once the source of the problem is identified. This is part of the 'subject matter as a whole' which should always be considered in determining the obviousness of an invention under 35 U.S.C. § 103." *In re Spinnoble*, 405 F.2d 578, 585, 160 USPQ 237, 243 (CCPA 1969). **(Emphasis added)**

KSR International v. Teleflex, Inc. et al., No. 04-1350, 550 U.S. __ (2007):

Finally, in the only post-*Graham* decision in which the Court has specifically ruled that a claimed invention is nonobvious, *United States v. Adams*, 383 U.S. 39 (1966), the Court did so without suggesting that the mere absence of any teaching, suggestion, or motivation from the prior art would be sufficient to overcome obviousness objections. See *id.* at 51-52. The Court ruled that the invention at issue—a water-activated, constant-voltage battery—was nonobvious, even though it combined elements that were “well known in the prior art” (*id.* at 51), because it demonstrated innovation beyond the level of ordinary skill in the art. The Court explained that the battery performed in a way that was “unexpected” and “far surpassed then-existing wet batteries” (*ibid.*); the teachings of the prior art would have “deter[red] any investigation” into the inventor’s combination (*id.* at 52); and “noted experts expressed disbelief in it” (*ibid.*).

Emphasis
added

35 U.S.C. 103(a). “The nonobviousness requirement extends the field of unpatentable material beyond that which is known to the public under § 102, to include that which could readily be deduced from publicly available material by a person of ordinary skill in the pertinent field of endeavor.” *Bonito Boats*, 489 U.S. at 150 (citing *Graham*, 383 U.S. at 15).

The question of nonobviousness is ultimately one of law, but it turns on “several basic factual inquiries.” *Graham*, 383 U.S. at 17. This Court has identified several such inquiries: (1) “the scope and content of the prior art”; (2) “differences between the prior art and the claims at issue”; and (3) “the level of ordinary skill in the pertinent art.” *Ibid.* In addition, the Court has stated that “secondary considerations,” such as “commercial success” or “long felt but unsolved needs,” might provide “indicia of obviousness or nonobviousness.” *Id.* at 17-18.

Emphasis
added

The “ultimate question” of patent validity under Section 103(a) is a question of law. *Graham*, 383 U.S. at 17. It rests on a legal judgment, informed by relevant facts, of whether the hypothetical person having ordinary skill in the art would have found the invention as a whole “obvious.” Section 103(a) itself identifies three “central factors relevant to any inquiry into obviousness” (*Johnston*, 425 U.S. at 226): the scope and content of the prior art, the differences between the prior art and the claims at issue, and the level of ordinary skill in the pertinent art. See *Graham*, 383 U.S. at 17. Other “secondary considerations” —including a long-felt and unfulfilled need for the invention, the prior failures of others, and the commercial success of the invention—may also provide “indicia” supporting the legal conclusion of “obviousness or nonobviousness.” *id.* at 17-18, 35-36, but those considerations will not render an obvious invention patentable. *Anderson’s-Black Rock, Inc. v. Pavement Salvage Co.*, 396 U.S. 57, 61 (1969) (citing *Great Atl. & Pac. Tea Co. v. Supermarket Equip. Corp.*, 340 U.S. 147, 153 (1950)).

Emphasis
added

4. The Federal Circuit’s perspective on the problem of hindsight is itself problematic. This Court cautioned in *Graham* against “read[ing] into the prior art the teachings of the invention in issue.” 383 U.S. at 36. The Court did not per-

Emphasis
added

ceive, however, any need for extraordinary showings of obviousness to avoid that danger. The Federal Circuit's rigid test underestimates the capacity of courts and the PTO to avoid the influence of hindsight. Retrospective analysis is not unique to patent law, but regularly arises in a wide variety of contexts, including the determination of the competency of counsel in criminal proceedings, see, e.g., *Rompilla v. Beard*, 125 S. Ct. 2456, 2462 (2005), reasonable use of force by police officers, see, e.g., *Graham v. Connor*, 490 U.S. 386, 396 (1989),

and probable cause, see, e.g., *Maryland v. Garrison*, 480 U.S. 79, 85 (1987). In those situations, as in *Graham*, the Court has consistently recognized that decisionmakers can avoid the improper influence of hindsight by maintaining conscious awareness of its potentially distorting influence in the decisionmaking process.¹⁰ Courts routinely find, for example, an absence of probable cause in cases in which the police in fact find substantial quantities of contraband in a search. There is no reason to think that courts in patent cases cannot be similarly discerning.

Emphasis
added

MPRP 716.05:

"Expressions of disbelief by experts constitute strong evidence of non-obviousness." *Environmental Designs, Ltd. v. Union Oil Co. of Cal.*, 713 F.2d 693, 698, 218 USPQ 865, 869 (Fed. Cir. 1983) (citing *United States v. Adams*, 383 U.S. 39, 52, 148 USPQ 479, 483-484 (1966)) (The patented process converted all the sulfur compounds in a certain effluent gas stream to hydrogen sulfide, and thereafter treated the resulting effluent for removal of hydrogen sulfide. Before learning of the patented process, chemical experts, aware of earlier failed efforts to reduce the sulfur content of effluent gas streams, were of the opinion that reducing sulfur compounds to hydrogen sulfide would not adequately solve the problem.).

"The skepticism of an expert, expressed before these inventors proved him wrong, is entitled to fair evidentiary weight, . . . as are the five to six years of research that preceded the claimed invention." *In re Dow Chemical Co.*, 837 F.2d 469, 5 USPQ2d 1529 (Fed. Cir. 1988); *Burlington Industries Inc. v. Quigg*, 822 F.2d 1581, 3 USPQ2d 1436 (Fed. Cir. 1987) (testimony that the invention met with initial incredulity and skepticism of experts was sufficient to rebut the *prima facie* case of obviousness based on the prior art)."

MPEP 2141.02 VI:

A prior art reference must be considered in its entirety, i.e., as a whole, including portions that would lead away from the claimed invention. *W.L. Gore & Associates, Inc. v. Garlock, Inc.*, 721 F.2d 1540, 220 USPQ 303 (Fed. Cir. 1983), *cert. denied*, 469 U.S. 851 (1984) (Claims were directed to a process of producing a porous article by expanding shaped, unsintered, highly crystalline poly(tetrafluoroethylene) (PTFE) by stretching said PTFE at a 10% per second rate to more than five times the original length. The prior art teachings with

regard to unsintered PTFE indicated the material does not respond to conventional plastics processing, and the material should be stretched slowly. A reference teaching rapid stretching of conventional plastic polypropylene with reduced crystallinity combined with a reference teaching stretching unsintered PTFE would not suggest rapid stretching of highly crystalline PTFE, in light of the disclosures in the art that teach away from the invention, i.e., that the conventional polypropylene should have reduced crystallinity before stretching, and that PTFE should be stretched slowly.). **(Emphasis added)**

MPEP 2145 D 1:

“A prior art reference that "teaches away" from the claimed invention is a significant factor to be considered in determining obviousness; however, "the nature of the teaching is highly relevant and must be weighed in substance. A known or obvious composition does not become patentable simply because it has been described as somewhat inferior to some other product for the same use." *In re Gurley*, 27 F.3d 551, 554, 31 USPQ2d 1130, 1132 (Fed. Cir. 1994)”

And, MPEP 2145 D 2:

“It is improper to combine references where the references teach away from their combination. *In re Grasselli*, 713 F.2d 731, 743, 218 USPQ 769, 779 (Fed. Cir. 1983) (The claimed catalyst which contained both iron and an alkali metal was not suggested by the combination of a reference which taught the interchangeability of antimony and alkali metal with the same beneficial result, combined with a reference expressly excluding antimony from, and adding iron to, a catalyst.).” **(Emphasis added)**

Applicant presents to the Examiner that the cited reference combinations do not comprise all of the cited limitations within the instant claims. Further, Applicant presents to the Examiner that Applicant has identified the source of the problem not identified by any of the cited references.

Applicant presents that a key Examiner reference, Scharpf et al, teaches away from the instant invention; as, Scharpf et al teach the addition of nitrogen to combustion therein diluting the concentration of oxygen while Applicant teaches the addition of pure oxygen to combustion as a means to reduce the concentration of nitrogen. Therefore, there are significant differences between the references and the instant claims. Further, Scharpf et al make the instant invention and the instant invention claims an irrational decision to one of ordinary skill in the art. As Scharpf et al make the instant invention and the instant claims irrational, the only method of obtaining the instant invention is by hindsight reconstruction.

Applicant presents to the Examiner that, as evidenced herein, Mr. James Kessling of the US DOD made many expressions of disbelief to the instant invention, as claimed, thereby demonstrating that the instant invention, as claimed, demonstrates innovation beyond the level of ordinary skill in the art. This is while the declarations of Mr. Vaughan and Mr. Walker demonstrate

that the engine of the instant invention far surpasses existing engines available today. To demonstrate this fact, Applicant knows of no other engine available today which operates burning hydrogen with pure oxygen while producing its own oxygen from air separation and while cooling the combustion chamber with water. Should the Examiner know of any engine which operates with the aforementioned attributes, Applicant welcomes the identification of such by the Examiner.

In summary, the evidence presented to the Examiner demonstrates that the instant invention, as claimed, is non-obvious per the MPEP and most recent U.S. Supreme Court Case Law.

CONCLUSION

In view of the foregoing, Applicant believes that the claims as presently amended, are in order for allowance; Applicant respectfully requests favorable reconsideration of this response and amendment, and allowance of the claims at the earliest opportunity.

Applicant has respectfully presented argument which demonstrates that the Examiner's cited reference combinations do not enable, teach or suggest all of the limitations of the instant claims.

Applicant has further respectfully presented secondary considerations in the form of three declarations, two from a person of ordinary skill in the art and one from a person of expert skill in the art, both of which demonstrate that the instant invention and the instant invention claims answer a long felt need, which has been recognized by those of ordinary skill in the art for some time and which was not answered prior to the filing of the instant invention.

Applicant has further still presented disbelief to the instant invention, as claimed, from a representative of the US DOD, wherein said representative is at least one of ordinary skill in the art while representing those who are of expert skill in the art.

Applicant has still further presented that the cited references teach away from the instant claims and the claimed invention. As the cited references, teach away, the only method of obtaining the instant invention from the cited references is by hindsight reconstruction.

Applicant appreciates the time and effort afforded by the Examiner in the prosecution of the instant claims for the instant invention.

As Applicant has respectfully traversed all of the Examiner's rejections, Applicant herein requests the award certificate for the instant claims as amended and presented herein.

Respectfully submitted,

A handwritten signature in black ink, appearing to read 'Richard A. Haase', written over a horizontal line.

Richard A. Haase, Pro Se' Applicant

Date: April 14, 2008

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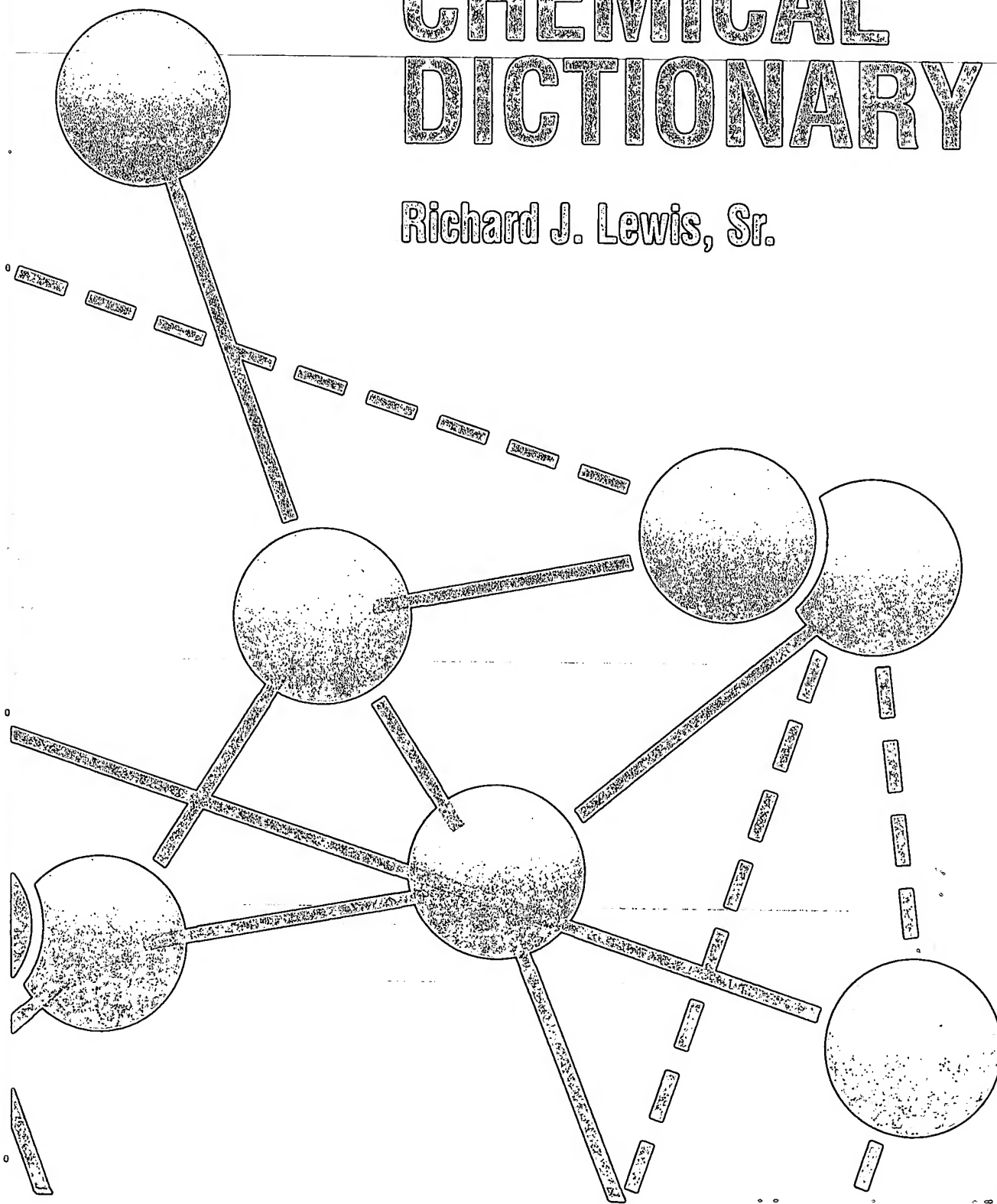
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Twelfth Edition

Hawley's

CONDENSED CHEMICAL DICTIONARY


Richard J. Lewis, Sr.



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CIP

The suspension is placed in a transparent container located in a solar concentrator.

carbon-black oil. A heavy refinery fraction similar to fuel oil, used as a feedstock for furnace black.

carbon, combined. A metallurgical term for carbon which has combined chemically with iron to form cementite, as distinct from graphitic carbon in iron or steel.
See also ferrite.

carbon cycle. (1) The progress of carbon from air (carbon dioxide) to plants by photosynthesis (sugar and starches), then through the metabolism of animals to decomposition products which ultimately return it to the atmosphere in the form of carbon dioxide. (2) One of the processes by which the sun and other self-luminous astronomical bodies are thought to derive their energy. The net process is the combination (fusion) of four hydrogen atoms to form helium. The carbon cycle involves successive additions of hydrogen atoms, followed by β decay, to an initial carbon-12 atom until a final step is reached in which the new nucleus breaks down to a helium atom and regenerated carbon-12. The carbon thus functions as a catalyst for the process. At the temperatures prevailing in the sun, all atoms are stripped of their electrons and the reaction is between the nuclei of the atoms (thermonuclear reaction). Symbolically the set of reactions is written

$$\begin{aligned} {}^{12}\text{C} + {}^1\text{H} &\rightarrow {}^{13}\text{N}, {}^{13}\text{N} \rightarrow {}^{13}\text{C} + e; \\ {}^{13}\text{C} + {}^1\text{H} &\rightarrow {}^{14}\text{N}, {}^{14}\text{N} + {}^1\text{H} \rightarrow {}^{15}\text{O}, \\ {}^{15}\text{O} &\rightarrow {}^{15}\text{N} + e, {}^{15}\text{N} \rightarrow {}^{12}\text{C} + {}^4\text{He}. \end{aligned}$$

See also fusion.

carbon dating. Radiocarbon dating is a method of determining quite accurately the age of a carbon-bearing material derived from living plants or animals within the last 70,000 years. It is based on determining the ratio of carbon-14 in the material to that in a modern reference sample by measuring the radioactivity of the carbon-14 in the material. Since the half-life of carbon-14 is 5730 30 years and the living precursor utilized carbon dioxide from the atmosphere or some other part of the earth's dynamic carbon reservoir, a process that ceased when the original plant or animal died, the amount of carbon-14 now present gives directly the age of the material. The carbon-14 in the reservoir is constantly being replaced by the sequence ${}^{14}\text{N} \rightarrow {}^{14}\text{C} + \text{O} \rightarrow {}^{14}\text{CO}_2$. This has maintained the ratio of carbon isomers constant during the ages; but burning of fossil fuels since the Industrial Revolution has lowered somewhat the fraction of carbon-14 in the atmosphere during the last few centuries, an effect that does not affect measure-

ments on older objects. The sample to be tested must be carefully prepared to prevent contamination by younger carbon.

The radiocarbon technique was discovered by Willard F. Libby (1908-1980; Nobel prize, 1960), and has been applied with great success in the fields of archeology, geology, geochemistry, and geophysics. Its accuracy has been checked and verified by use of tree-ring counts (dendrochronology) and with the known ages of objects from ancient cultures, such as Egyptian and Chinese. The former shows that for the 2400-6000 year age of bristlecone-pine tree-rings, 5,200 ${}^{14}\text{C}$ years equal 6,000 calendar years.

carbon dichloride. See perchloroethylene.

carbon dioxide. CAS: 124-38-9. CO_2 .
18th highest-volume chemical produced in the U.S. (1991).

Properties: (1) Gas: colorless, odorless, d 1.97 g/L (0C, 1 atm); d 1.53 (air = 1.00); (2) liquid: volatile, colorless, odorless, d 1.101 (-37C), sp volume 8.76 cu ft/lb (70F); (3) solid (dry ice): white, snow-like flakes or cubes; d 1.56 (-79C); mp -78.5C (sublimes). All forms are non-combustible. Miscible with water (1.7 volumes per volume at 0C and 0.76 volume per volume at 25C and 760 mm Hg partial pressure of CO_2). Also miscible with hydrocarbons and most organic liquids. An asphyxiant gas in concentrations of 10% or more; low concentrations (1-3%) increase lung ventilation and are used admixed with oxygen in resuscitation equipment.

Derivation: (1) Gas: for industrial use, carbon dioxide is recovered from synthesis gas in ammonia production, from substitute-natural-gas production, from cracking of hydrocarbons, and from natural springs or wells. For laboratory purposes it is obtained by the action of an acid on a carbonate. It is also a by-product of the fermentation of carbohydrates and an end product of combustion and respiration. Air contains 0.033% of carbon dioxide (see greenhouse effect). (2) Liquid: by compressing and cooling the gas to approximately -37C. (3) Solid (dry ice): by expanding the liquid to vapor and snow in presses that compact the product into blocks. The vapor is recycled.

Grade: Technical, USP, commercial and welding, 99.5%, bone dry (99.95%).

Hazard: Solid damaging to skin and tissue; keep away from mouth and eyes. TLV (gas): 5000 ppm in air.

Use: Refrigeration, carbonated beverages, aerosol propellant, chemical intermediate (carbonates, synthetic fibers, p-xylene, etc.), low-temperature testing, fire extinguishing, inert atmospheres, municipal water treatment, medicine, enrichment of air in greenhouses, fracturing and acidizing of oil wells, mining (Cardox

iponitrile, cyanide salts, dyes, chelates, rodenticides, pesticides.

"Hydro-Darco" [*American Norit*]. TM for activated carbon based adsorbent.

Use: For purification of water, fine chemicals, waste water, air, and pharmaceuticals. Used for recovery of valuable products as in gold and organic solvents.

hydrodealkylation. (HDA). A type of hydrogenation used in petroleum refining in which heat and pressure in the presence of hydrogen are used to remove methyl or larger alkyl groups from hydrocarbon molecules, or to change the position of such groups. The process is used to upgrade products of low value, such as heavy reformat fractions, naphthenic crudes, or recycle stocks from catalytic cracking. Also toluene and pyrolysis gasoline are converted to benzene and methyl naphthalenes to naphthalene by this process.

See also transalkylation.

hydrodistillation. (steam distillation). Removal of essential oils from plant components (flowers, leaves, bark, etc.) by the use of high-temperature steam. The process is used chiefly in the perfume and fragrance industry.

hydrofining. A petroleum refining process in which a limited amount of hydrogenation converts the sulfur and nitrogen in a petroleum fraction to forms in which they can be easily removed. Hydrofining is generally a separate treatment prior to more extensive hydrogenation. The usual catalysts are oxides of cobalt and molybdenum. Desulfurization, ultrafining, and catfining have a similar meaning.

hydroflumethiazide. (trifluoromethylhydrothiazide). CAS: 135-09-1. $C_8H_8F_3N_3O_4S_2$.

Properties: White, crystalline, odorless solid. Mp 260-275C, insoluble in water and acid, soluble in dilute alkali but unstable in alkaline solutions. Grade: NF.

Use: Medicine (antihypertensive).

hydrofluoric acid. CAS: 7664-39-3. Hydrogen fluoride in aqueous solution.

Properties: Colorless, fuming, mobile liquid; bp (38% solution) 112C. Will attack glass and any silicon-containing material.

Derivation: Dissolving hydrogen fluoride in water to various concentrations.

Grade: CP, technical, 38%, 47%, 53%, 70%.

Hazard: Toxic by ingestion and inhalation, highly corrosive to skin and mucous membranes. TLV: ceiling 3 ppm.

Use: Aluminum production, fluorocarbons, pickling stainless steel, etching glass, acidizing

oil wells, fluorides, gasoline production (alkylation), processing uranium.
See also hydrogen fluoride.

hydrofluorosilicic acid. Legal label name (Rail) for fluosilicic acid.

hydrofluosilicic acid. See fluosilicic acid.

"Hydrofol" [*Sherex*]. (behenic acid).

CAS: 112-85-6. TM for synthetic waxes.

Use: For lubricants, esters, chemical synthesis, and specialties.

"Hydrofol" [*Ashland*]. (stearic acid).

CAS: 57-11-4. TM for an additive.

Use: In esters, greases, candles, crayons, cosmetics, metallic salts, mono- and diglyceride, shaving creams, textile auxiliaries, white stearates, waxes, and rubber compounding.

hydroforming. The use of hydrogen in the presence of heat, pressure, and catalysts (usually platinum) to convert olefinic hydrocarbons to branched-chain paraffins (isomerization) to yield high-octane gasoline. Catforming and similar terms are often used in the same sense.

hydrofuramide. (furfuramide). CAS: 494-47-3. $OC_4H_3CH(NCHC_4H_3O)_2$.

Properties: Light brown to white powder, mp 117C, boils about 250C with decomposition, insoluble in cold water, soluble in alcohol and ether.

Derivation: Treatment of furfural with ammonia.

Use: Rubber accelerator, hardening agent for resins, rodenticides, fungicides.

hydrogasification. Production of gaseous or liquid fuels by direct addition of hydrogen to coal. See also gasification.

hydrogen. CAS: 1333-74-0. H_2 . Nonmetallic element of atomic number 1, group IA of periodic table, atomic weight 1.0079, valence of 1. Molecular formula is H_2 . Isotopes: deuterium (2D), tritium (3T). Hydrogen discovered by Cavendish in 1766, named by Lavoisier in 1783.

Properties: A diatomic gas, density 0.08999 g/L, d 0.0694 (air = 1.0), specific volume 193 cu ft/lb (21.1C), fp -259C, bp -252C, autoign temperature 1075F (580C). Very slightly soluble in water, alcohol, and ether; Noncorrosive; can exist in crystalline state at from 4-1 K; classed as an asphyxiant gas; rate of permeation through solids is approximately four times that of air.

Occurrence: Chiefly in combined form (water, hydrocarbons, and other organic compounds),

minum, zinc, lead, and tin; soluble in hydrogen fluoride.

Derivation: Reaction of powdered silicon and nitrogen in an electric furnace at 1300C.

Use: Refractory coatings, bonding silicon carbide, mortars, abrasives, thermocouple tubes in molten aluminum, crucibles for zone-refining germanium, rocket nozzles, high-strength fibers and whiskers, insulator and passivating agent in transistors and other solid-state devices.

silicon tetrabromide. (tetrabromosilane).

CAS: 7789-66-4. SiBr_4 .

Properties: Fuming, colorless liquid which turns yellow in air; disagreeable odor. Decomposed by water with evolution of heat, d 2.82 (0C), bp 153C, mp 5C. Non-combustible. Purity: 99.999%.

Hazard: Strong irritant to tissue.

silicon tetrachloride. (tetrachlorosilane; silicon chloride). CAS: 10026-04-7. SiCl_4 .

Properties: Colorless, exceedingly mobile, fuming liquid; suffocating odor. Corrosive to most metals when water is present; in the absence of water, it has practically no action on iron, steel, or the common metals and alloys, and can be stored and handled in metal equipment without danger. D 1.483 (20C), bulk d 12.4 lb/gal, fp -70C, bp 57.6C, $refr$ index 1.412 (20C). Miscible with carbon tetrachloride, tin tetrachloride, titanium tetrachloride, and sulfur mono- and dichlorides; decomposed by water and alcohol with evolution of hydrogen chloride. Non-combustible.

Derivation: Heating silicon dioxide and coke in a stream of chlorine.

Grade: Technical, 99.5%, CP (99.8%), semi-conductor.

Hazard: Toxic by ingestion and inhalation, strong irritant to tissue.

Use: Smoke screens; manufacture of ethyl silicate and similar compounds; production of silicones; manufacture of high-purity silica and fused silica glass; source of silicon, silica, and hydrogen chloride; lab reagent.

silicon tetrafluoride. (tetrafluorosilane; silicon fluoride). CAS: 7783-61-1. SiF_4 .

Properties: Colorless gas, suffocating odor similar to hydrogen chloride, fumes strongly in air, d 3.57 (gas, air = 1) (15C), fp -90C, bp -86C, absorbed readily in large quantities by water with decomposition, soluble in absolute alcohol. Non-combustible.

Derivation: (1) Action of hydrogen fluoride or concentrated sulfuric acid and a metallic fluoride on silica or silicates. (2) Direct synthesis.

Grade: Pure, 99.5% min.

Hazard: Toxic by inhalation, strong irritant to

mucous membranes. TLV (as F): 2.5 mg/m³ of air.

Use: Manufacture of fluosilicic acid, intermediate in manufacture of pure silicon, to seal water out of oil wells during drilling.

silicon tetrahydride. See silane.

silicon tetraiodide. SiI_4 .

Properties: White crystals, mp 120C, bp 290C.

Non-combustible.

Purity: Up to 99.999%.

Hazard: Toxic by ingestion and inhalation, irritant to tissue.

silicotungstic acid. (12-tungstosilicic acid; silicowolframic acid). CAS: 12027-38-2.

$\text{H}_4\text{SiW}_{12}\text{O}_{40} \cdot 5\text{H}_2\text{O}$.

Properties: White, crystalline powder. Very soluble in water and polar organic solvents, relatively insoluble in non-polar organic solvents, strong acid. Non-combustible.

Grade: Reagent, technical.

Use: Catalyst for organic synthesis, reagent for alkaloids, additive to plating processes, as precipitant and inorganic ion-exchanger, minerals separation, mordant.

See also sodium 12-tungstosilicate and tungstosilicates.

silicowolframic acid. See silicotungstic acid.

silk. A natural fiber secreted as a continuous filament by the silkworm, *Bombyx mori*; silk consists essentially of the protein fibroin and, in the raw state, is coated with a gum that is usually removed before spinning. D 1.25, elongation at rupture about 20%, tenacity 3-5 g/denier. Combustible but self-extinguishing.

sillimanite. An aluminum silicate, a high heat-resisting material containing a maximum amount of mullite, developed from the alteration of andalusite during firing. This necessitates firing at above 1550C for the development of a suitable crystalline structure.

Use: Spark plugs, chemical lab ware, pyrometer tubes, special porcelain shapes, furnace patches, and refractories.

silos. See ensilage.

siloxane. (oxosilane). A straight-chain compound (analogous to paraffin hydrocarbons) consisting of silicon atoms single-bonded to oxygen and so arranged that each silicon atom is linked with four oxygen atoms.

(polystyrene bottles) to render them biodegradable. (6) High-pressure hydrogenation of garbage to yield a low-sulfur combustible oil. (7) Deactivating radioactive wastes by adsorption or ion exchange, as well as by solidification and hydraulic fracturing; high-activity wastes are buried in steel-lined concrete tanks. (8) Catalytic oxidation of waste chlorinated hydrocarbons, with partial recovery of chlorine. (9) Incineration of semi-solid and liquid wastes at sea in ships designed for that purpose. See also radioactive waste, chemical waste, sewage sludge, urban waste.

waste, hazardous. See chemical waste, radioactive waste.

waste, radioactive. See radioactive waste.

waste wool, wet. See wool waste.

"Watchung" [Du Pont]. TM for precipitated diazo red pigments.

water. (ice, steam). H_2O or HOH . Properties: Colorless, odorless, tasteless liquid. Allotropic forms are ice (solid) and steam (vapor). Water is a polar liquid with high dielectric constant (81 at 17°C), which largely accounts for its solvent power. It is a weak electrolyte, ionizing as H_3O^+ and OH^- . At atmospheric pressure it has d 1.00 (4°C), fp 0°C (32°F) and expands about 10% on freezing. Viscosity 0.01002 poise (20°C), sp heat 1 calorie/g, vap press 760 mm Hg (100°C), triple point 273.16K at 4.6 mm, surface tension 73 dynes/cm at 20°C, latent heat of fusion (ice) 80 cal/g, latent heat of condensation (steam) 540 cal/g. Bulk d 8.337 lb/gal, 62.3/lb/cu ft. Refr index 1.333. Water may be superheated by enclosing in an autoclave and increasing pressure; it may be supercooled by adding sodium chloride or other ionizing compound. It has definite catalytic activity, especially of metal oxidation. Physiologically water is classed as a nutrient substance.

Derivation: (1) Oxidation of hydrogen, (2) end product of combustion, (3) end product of acid-base reaction, (4) end product of condensation reaction.

Purification: (1) Distillation, (2) ion-exchange reaction (zeolite), (3) chlorination, (4) filtration.

Use: Suspending agent (papermaking, coal slurries), solvent (extraction, scrubbing), diluent, beer and carbonated beverages, hydration of lime, paper coatings, textile processing, moderator in nuclear reactors, debarking logs, industrial coolant, filtration, washing and scouring, sulfur mining, hydrolysis, Portland cement, hydraulic systems, power source, steam generation, food industry, source of hydrogen by electrolysis and thermochemical decomposition.

See hydrogen. See also ice; steam; heavy water; ocean water; water, hard.

water, bound. See bound water.

water gas. (blue gas). A mixture of gases made from coke, air, and steam. The steam is decomposed by passing it over a bed of incandescent coke, or by high-temperature reaction with natural gas or similar hydrocarbons. Approximate composition: carbon monoxide 40%, hydrogen 50%, carbon dioxide 3%, and nitrogen 3%.

Hazard: Flammable, dangerous fire and explosion risk. Explosive limits 7-72% in air. Toxic by inhalation.

Use: Organic synthesis, fuel gas, ammonia synthesis.

See also synthesis gas.

water glass. See sodium silicate.

water, hard. Water containing low percentages of calcium and magnesium carbonates, bicarbonates, sulfates, or chlorides, as a result of long contact with rocky substrates and soils. Degree of hardness is expressed either as grains per gallon or parts per million (ppm) of calcium carbonate (1 grain of $CaCO_3$ per gal is equivalent to 17.1 ppm). Up to 5 grains is considered soft, over 30 grains is very hard. Hardness may be temporary (carbonates and bicarbonates) or permanent (sulfates, chlorides). Treatment with zeolites is necessary to soften permanently hard water. Temporary hardness can be reduced by boiling. These impurities are responsible for boiler scale and corrosion of metals on long contact. Hard waters require use of synthetic detergents for satisfactory "sudsing." See also zeolite.

watermark. See dandy roll.

water of crystallization. Water chemically combined in many crystallized substances; it can be removed at or near 100°C, usually with loss of crystalline properties.

water pollution. Contamination of fresh or salt water with materials that are toxic, noxious, or otherwise harmful to fish and other animals and to man, including thermal pollution. Disposal of untreated chemical and municipal wastes in streams and rivers has been illegal since the early 1900s; in 1973 the EPA prohibited dumping of all types of wastes into the ocean. Unintentional pollution results from run-off containing toxic insecticidal residues. Oil spills at sea are a continual problem and probably will remain so. See also waste treatment, oil spill treatment, Environmental Protection Agency, environmental chemistry.

Gasification

From Wikipedia, the free encyclopedia

Gasification is a process that converts carbonaceous materials, such as coal, petroleum, or biomass, into carbon monoxide and hydrogen by reacting the raw material at high temperatures with a controlled amount of oxygen. The resulting gas mixture is called synthesis gas or syngas and is itself a fuel. Gasification is a very efficient method for extracting energy from many different types of organic materials, and also has applications as a clean waste disposal technique.

The advantage of gasification is that using the syngas is more efficient than direct combustion of the original fuel; more of the energy contained in the fuel is extracted. Syngas may be burned directly in internal combustion engines, used to produce methanol and hydrogen, or converted via the Fischer-Tropsch process into synthetic fuel. Gasification can also begin with materials that are not otherwise useful fuels, such as biomass or organic waste. In addition, the high-temperature combustion refines out corrosive ash elements such as chloride and potassium, allowing clean gas production from otherwise problematic fuels.

Gasification of fossil fuels is currently widely used on industrial scales to generate electricity. However, almost any type of organic material can be used as the raw material for gasification, such as wood, biomass, or even plastic waste. Thus, gasification may be an important technology for renewable energy. In particular biomass gasification is carbon neutral.

Gasification relies on chemical processes at elevated temperatures $>700^{\circ}\text{C}$, which distinguishes it from biological processes such as anaerobic digestion that produce biogas.

Contents

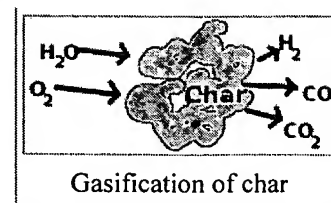
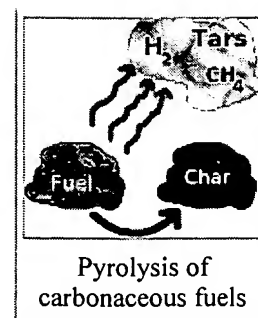
- 1 Chemistry
- 2 History
- 3 Current applications
- 4 Potential for renewable energy
- 5 Gasification processes
- 6 Waste disposal
- 7 See also
- 8 External links
- 9 References

Chemistry

In a gasifier, the carbonaceous material undergoes several different processes:

1. The *pyrolysis* (or devolatilization) process occurs as the carbonaceous particle heats up. Volatiles are released and char is produced, resulting in up to 70% weight loss for coal. The process is dependent on the properties of the carbonaceous material and determines the structure and composition of the char, which will then undergo gasification reactions.

- The *combustion* process occurs as the volatile products and some of the char reacts with oxygen to form carbon dioxide and carbon monoxide, which provides heat for the subsequent gasification reactions. Letting C represent a carbon-containing organic compound, the basic reaction here is $C + \frac{1}{2}O_2 \rightarrow CO$
- The *gasification* process occurs as the char reacts with carbon dioxide and steam to produce carbon monoxide and hydrogen, via the reaction $C + H_2O \rightarrow H_2 + CO$
- In addition, the reversible gas phase water gas shift reaction reaches equilibrium very fast at the temperatures in a gasifier. This balances the concentrations of carbon monoxide, steam, carbon dioxide and hydrogen. $CO + H_2O \leftrightarrow CO_2 + H_2$



In essence, a limited amount of oxygen or air is introduced into the reactor to allow some of the organic material to be "burned" to produce carbon monoxide and energy, which drives a second reaction that converts further organic material to hydrogen and additional carbon dioxide.

History

The gasification process was originally developed in the 1800s to produce town gas for lighting and cooking. Electricity and natural gas later replaced town gas for these applications, but the gasification process has been utilized for the production of synthetic chemicals and fuels since the 1920s.

Wood gas generators, called Gasogene or *Gazogène*, were used to power motor vehicles in Europe during World War II fuel shortages.^[1]

Current applications

Industrial-scale gasification is currently mostly used to produce electricity from fossil fuels such as coal, where the syngas is burned in a gas turbine.

Gasification is also used industrially in the production of electricity, ammonia and liquid fuels (oil) using Integrated Gasification Combined Cycles (IGCC), with the possibility of producing methane and hydrogen for fuel cells. IGCC is also a more efficient method of CO₂ capture as compared to conventional technologies. IGCC demonstration plants have been operating since the early 1970s and some of the plants constructed in the 1990s are now entering commercial service.

Within the last few years, gasification technologies have been developed that use plastic-rich waste as a feed. In a plant in Germany such a technology—on large scale—converts plastic waste via syngas into methanol.^[2]

Small-scale rural biomass gasifiers have been applied in India to a large extent, especially in the state of Tamil-Nadu in South India. Most of the applications are 9 kWe systems used for (drink) water pumping and street lighting operated by the local panchayat government. Although technically applicable the systems do face a number of problems. There are political, financial and maintenance problems. Most of the systems are no longer running after 1...3 years.

Potential for renewable energy

Gasification can proceed from just about any organic material, including biomass and plastic waste. The resulting syngas burns cleanly into water vapor and carbon dioxide. Alternatively, syngas may be converted efficiently to methane via the Sabatier reaction, or diesel-like synthetic fuel via the Fischer-Tropsch process. Inorganic components of the input material, such as metals and minerals, are trapped in an inert and environmentally safe form as ash, which may have use as a fertilizer.

Regardless of the final fuel form, gasification itself and subsequent processing neither emits nor traps greenhouse gasses such as carbon dioxide. Combustion of syngas or derived fuels does of course emit carbon dioxide. However, biomass gasification could play a significant role in a renewable energy economy, because biomass production removes CO₂ from the atmosphere. While other biofuel technologies such as biogas and biodiesel are also carbon neutral, gasification runs on a wider variety of input materials, can be used to produce a wider variety of output fuels, and is an extremely efficient method of extracting energy from biomass.

Biomass gasification is therefore one of the most technically and economically convincing energy possibilities for a carbon neutral economy ^[3].

There is at present very little industrial scale biomass gasification being done. The Renewable Energy Network Austria^[4] is associated with several successful biomass gasification demonstration projects, including a plant using dual fluidized bed gasification^[5] that has supplied the town of Güssing with 2 MW of electricity and 4 MW of heat, generated from wood chips, since 2003.

Gasification processes

Four types of gasifier are currently available for commercial use: counter-current fixed bed, co-current fixed bed, fluidized bed and entrained flow.^{[6][7][8]}

The **counter-current fixed bed ("up draft") gasifier** consists of a fixed bed of carbonaceous fuel (e.g. coal or biomass) through which the "gasification agent" (steam, oxygen and/or air) flows in counter-current configuration. The ash is either removed dry or as a slag. The slagging gasifiers require a higher ratio of steam and oxygen to carbon in order to reach temperatures higher than the ash fusion temperature. The nature of the gasifier means that the fuel must have high mechanical strength and must be non-caking so that it will form a permeable bed, although recent developments have reduced these restrictions to some extent. The throughput for this type of gasifier is relatively low. Thermal efficiency is high as the gas exit temperatures are relatively low. However, this means that tar and methane production is significant at typical operation temperatures, so product gas must be extensively cleaned before use or recycled to the reactor.

The **co-current fixed bed ("down draft") gasifier** is similar to the counter-current type, but the gasification agent gas flows in co-current configuration with the fuel (downwards, hence the name "down draft gasifier"). Heat needs to be added to the upper part of the bed, either by combusting small amounts of the fuel or from external heat sources. The produced gas leaves the gasifier at a high temperature, and most of this heat is often transferred to the gasification agent added in the top of the bed, resulting in an energy efficiency on level with the counter-current type. Since all tars must pass through a hot bed of char in this configuration, tar levels are much lower than the counter-current type.

In the **fluidized bed reactor**, the fuel is fluidized in oxygen and steam or air. The ash is removed dry or as heavy agglomerates that defluidize. The temperatures are relatively low in dry ash gasifiers, so the fuel must be highly reactive; low-grade coals are particularly suitable. The agglomerating gasifiers have slightly higher temperatures, and are suitable for higher rank coals. Fuel throughput is higher than for the fixed bed, but not as high as for the entrained flow gasifier. The conversion efficiency can be rather low due to elutriation of carbonaceous material. Recycle or subsequent combustion of solids can be used to increase conversion. Fluidized bed gasifiers are most useful for fuels that form highly corrosive ash that would damage the walls of slagging gasifiers. Biomass fuels generally contain high levels of corrosive ash.

In the **entrained flow gasifier** a dry pulverized solid, an atomized liquid fuel or a fuel slurry is gasified with oxygen (much less frequent: air) in co-current flow. The gasification reactions take place in a dense cloud of very fine particles. Most coals are suitable for this type of gasifier because of the high operating temperatures and because the coal particles are well separated from one another. The high temperatures and pressures also mean that a higher throughput can be achieved, however thermal efficiency is somewhat lower as the gas must be cooled before it can be cleaned with existing technology. The high temperatures also mean that tar and methane are not present in the product gas; however the oxygen requirement is higher than for the other types of gasifiers. All entrained flow gasifiers remove the major part of the ash as a slag as the operating temperature is well above the ash fusion temperature. A smaller fraction of the ash is produced either as a very fine dry fly ash or as a black colored fly ash slurry. Some fuels, in particular certain types of biomasses, can form slag that is corrosive for ceramic inner walls that serve to protect the gasifier outer wall. However some entrained bed type of gasifiers do not possess a ceramic inner wall but have an inner water or steam cooled wall covered with partially solidified slag. These types of gasifiers do not suffer from corrosive slags. Some fuels have ashes with very high ash fusion temperatures. In this case mostly limestone is mixed with the fuel prior to gasification. Addition of a little limestone will usually suffice for the lowering the fusion temperatures. The fuel particles must be much smaller than for other types of gasifiers. This means the fuel must be pulverized, which requires somewhat more energy than for the other types of gasifiers. By far the most energy consumption related to entrained bed gasification is not the milling of the fuel but the production of oxygen used for the gasification.

Waste disposal

Several gasification processes for thermal treatment of waste are under development as an alternative to incineration.

Waste gasification has several principal advantages over incineration:

- The necessary extensive flue gas cleaning may be performed on the syngas instead of the much larger volume of flue gas after combustion.
- Electric power may be generated in engines and gas turbines, which are much cheaper and more efficient than the steam cycle used in incineration. Even fuel cells may potentially be used, but these have rather severe requirements regarding the purity of the gas.
- Chemical processing of the syngas may produce other synthetic fuels instead of electricity.
- Some gasification processes treat ash containing heavy metals at very high temperatures so that the it is released in a glassy and chemically stable form.

A major challenge for waste gasification technologies is to reach an acceptable (positive) gross electric efficiency. The high efficiency of converting syngas to electric power is counteracted by significant power consumption in the waste preprocessing, production of large amounts of pure oxygen (which is often used as gasification agent), and gas cleaning. Another challenge becoming apparent when implementing the processes in real life is to obtain long service intervals in the plants, so that it is not necessary to close down the plant every few months for cleaning the reactor.

Several waste gasification processes have been proposed, but few have yet been built and tested, and only a handful have been implemented as plants processing real waste, and always in combination with fossil fuels^[10].

One plant (in Chiba, Japan using the Thermoselect process^[11]) has been processing industrial waste since year 2000, but has not yet documented positive net energy production from the process.

See also

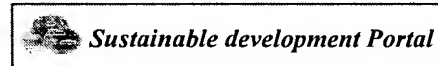
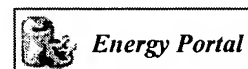
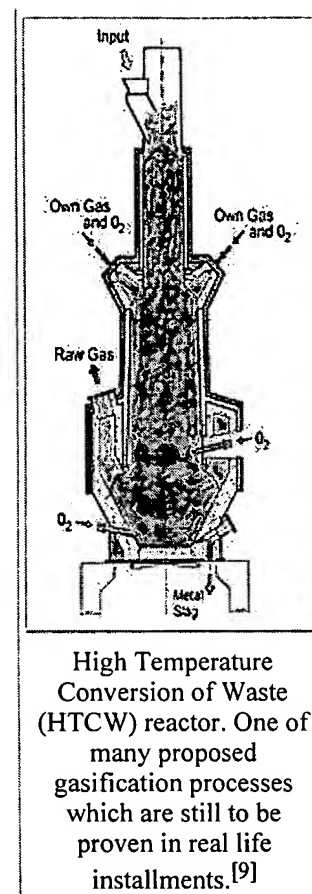
- Biofuel
- FutureGen zero-emissions coal-fired power plant
- Fluidized bed
- Fluidized bed combustion
- Isle of Wight gasification facility
- List of solid waste treatment technologies
- Plasma arc waste disposal
- Renewable natural gas
- Synthetic fuel

External links

- Pyrolysis and Gasification Factsheet
- Carbon cycle management with increased photo-synthesis and long-term sinks,
- Heat Transfer International Biomass Technology Experts
- "Gasification Technology" Experts from CGPL, Indian Institute of Science

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2. ^ Converting waste to methanol



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